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Monitoring of subsurface extended cavities prone to instabilities

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Natural or abandoned anthropogenic cavities are to be found in various contexts all around the world. In France, shallow cavities count rises up to several hundreds of thousands. It concerns complex cavities as old abandoned multilevel quarries, extended mines or naturally interlaced karsts. Risk assessment related to these cavities, such as sinkholes or pillar failure, conducts usually to short term strategy based on regular visual inspections until a more definitive risk reduction strategy is adopted. However, if no definitive remediation appears as feasible, for technical or socio-economic reasons, monitoring by regular visual inspection of specialists rises several crucial issues in the long term: safety conditions for the inspection team, limited reactivity of the monitoring due to the period between two inspections and finally difficulties to detect reliably and exhaustively early signs of evolution when local disorders are spread over a large underground area.

Several well-proofed techniques are available to detect subsurface cavities, but it is less common when considering field instrumentation applied to permanent monitoring in such context. Indeed, classical geotechnical measurement based on strain and displacement sensors give very local information and cannot be deployed at a large scale with a correct coverage within a reasonable cost/benefit ratio. Moreover this type of instrumentation requires significant efforts and equipment for installation underground, must be placed right inside the most hazardous zones whenever it is feasible and is often not retrievable.

Yet a continuous remote monitoring can save a regular control on site and may provide unique information about the kinetic of potential sinkholes and local ground failures. To proceed with this matter, INERIS develops and tests new tools and methods to facilitate the setting up of operational devices for remote monitoring and alert applied to subsurface extended cavities. Such systems aim to detect and characterize unstable evolution, especially sinkholes, and to circumvent all issues mentioned previously.

Thus, among the different approaches currently studied, the most promising is aerial acoustic listening. Along with microseismic, this method enables volumetric monitoring over a large extended area characterized by deep quietness. Specific high sensitivity microphone probes have been developed and surveys have been conducted in two abandoned iron mines. Dimensioning physical parameters, depending on the geometry of the site and the density of sensors, were measured: listening area, acoustic sensitivity and velocity, attenuation of pressure waves, etc. Off-line processing of source localization was also studied and very good results were obtained. Along with acoustic listening, alternative new sensors are tested, as rock debris falls detecting nets installed in selected areas and easy-to-anchor microseismic probes for detection of fracturing processes inside the surrounding mass.

The paper the authors intend to present will describe the research and field work conducted in this domain thanks to the French ministry of ecology and sustainable development. Principal results, limitations and recommendations concerning tested techniques and associated strategies will be discussed. Feedback from an operational system run in a closed salt mine will also be illustrated and discussed.